

Calibrating Spaceborne Microwave Radiometers with GPS

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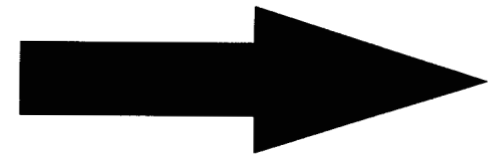
Intl. Union of Geodesy and Geophysics, July 26, 1999

Introduction

Data from terrestrial GPS receivers are being used in growing numbers of applications requiring precise tropospheric sensing. One emerging application is the calibration of water vapor measurements from spaceborne microwave radiometers. An excellent candidate mission for developing this technology is Topex/Poseidon (T/P). A joint U.S./France mission launched in 1992 to measure global ocean circulation and sea level, T/P carries a microwave radiometer to provide measurements of wet path delay with cm-level accuracy. The nadir-looking Topex microwave radiometer (TMR) was included to provide a columnar water vapor delay correction for the altimeter range measurements used in forming the sea-surface height measurements. As such, any spurious drift in the TMR measurements can map significantly into the estimated rate of change in global mean sea level from T/P.

By virtue of their proximity to open-ocean T/P repeat tracks, many stations in the rapidly growing GPS global network are well suited for monitoring the TMR. For these locations, we are constructing time series based on the differences of the instantaneous vertical wet path delay derived independently from the TMR and GPS data at T/P overflight times. Using data from four GPS stations with the longest and most consistent tracking histories, we concluded that the TMR measurements of wet path delay drifted lower by 1 mm/yr from 1992-97. We discuss the challenges encountered in using these long-term GPS time series as a calibration tool. We also present new TMR drift and scale error estimates from an extended analysis incorporating additional GPS stations. Finally, we discuss plans and prospects for calibrating the radiometer on the T/P follow-on mission (Jason-1), scheduled for launch in May, 2000.

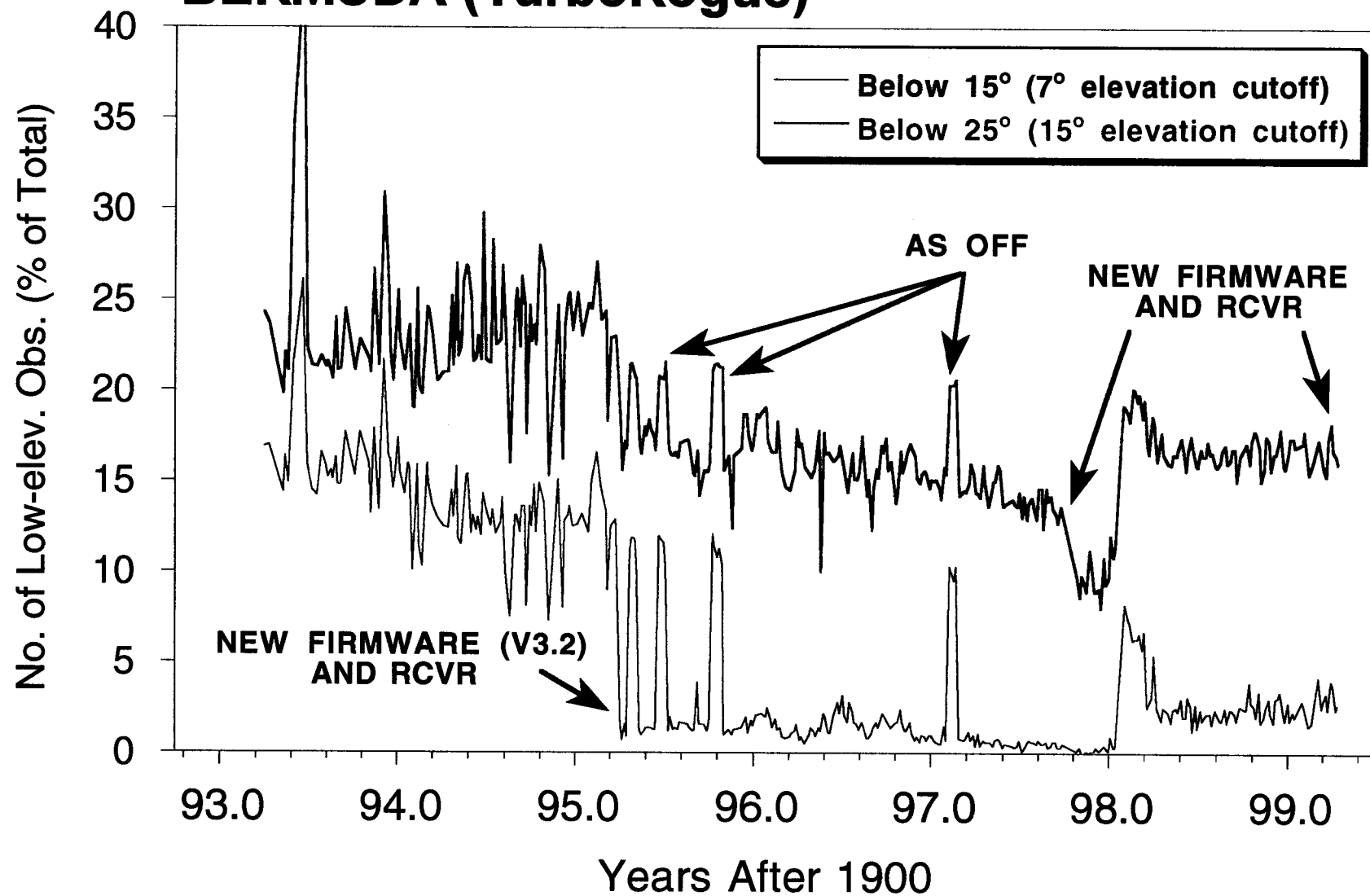
LOW ELEVATION TRACKING HISTORY



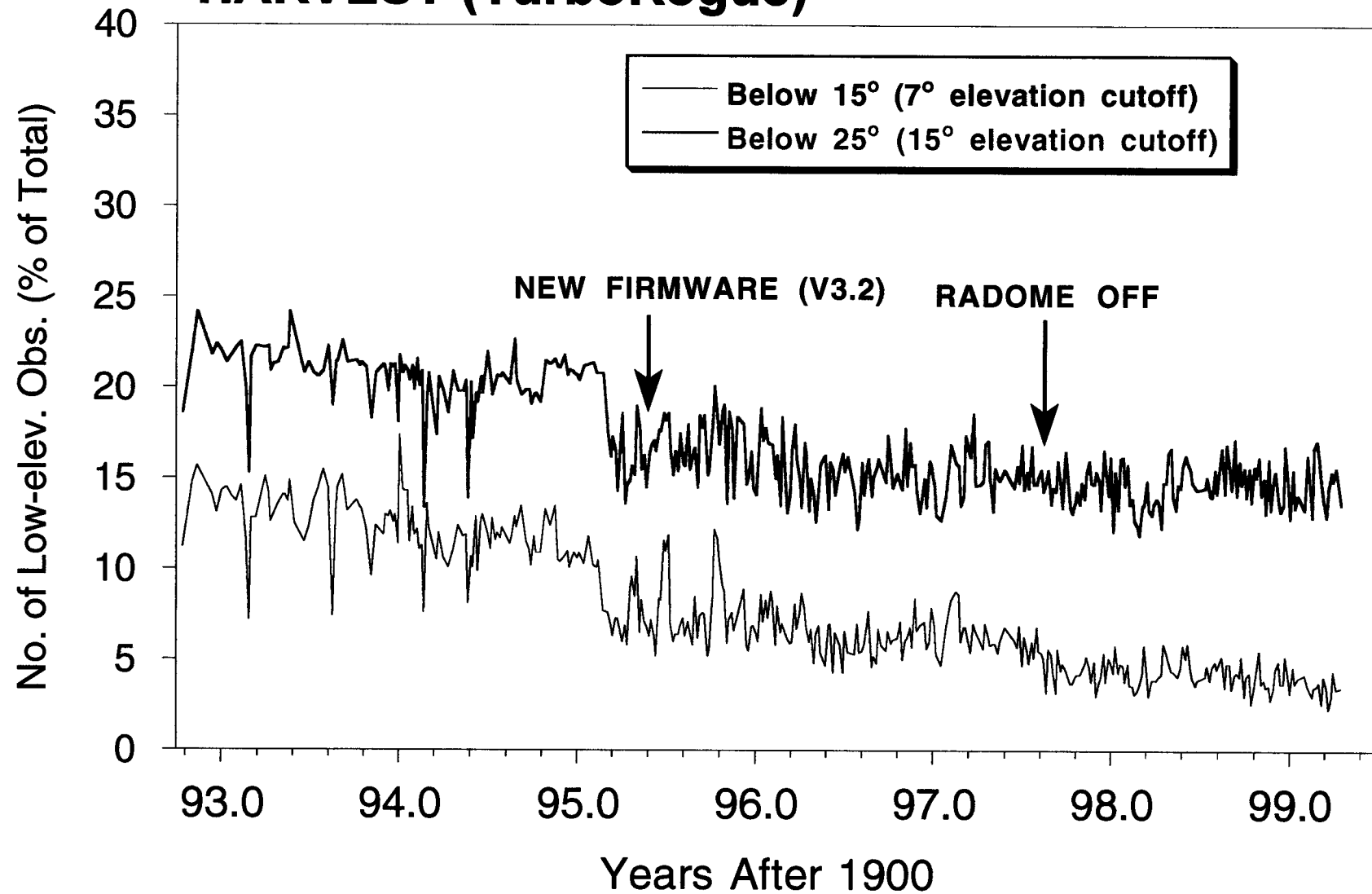
The recovery of GPS Vertical Parameters (Height and Water Vapor Delay) is sensitive to low-elevation data. Shown here are long-term trends in abundance of low-elevation data (postfit) at four GPS tracking stations with long occupation histories.

Station	Location	Lat.	Install	$\overline{PD}_{\text{wet}}$ (cm)
Bermuda	N. Atlantic island	32N	3/93	18
Harvest	Calif. offshore rig	34N	6/92	10
Metsahovi	Gulf of Finland coast	60N	5/92	9
Onsala	North Sea coast	57N	7/93	9

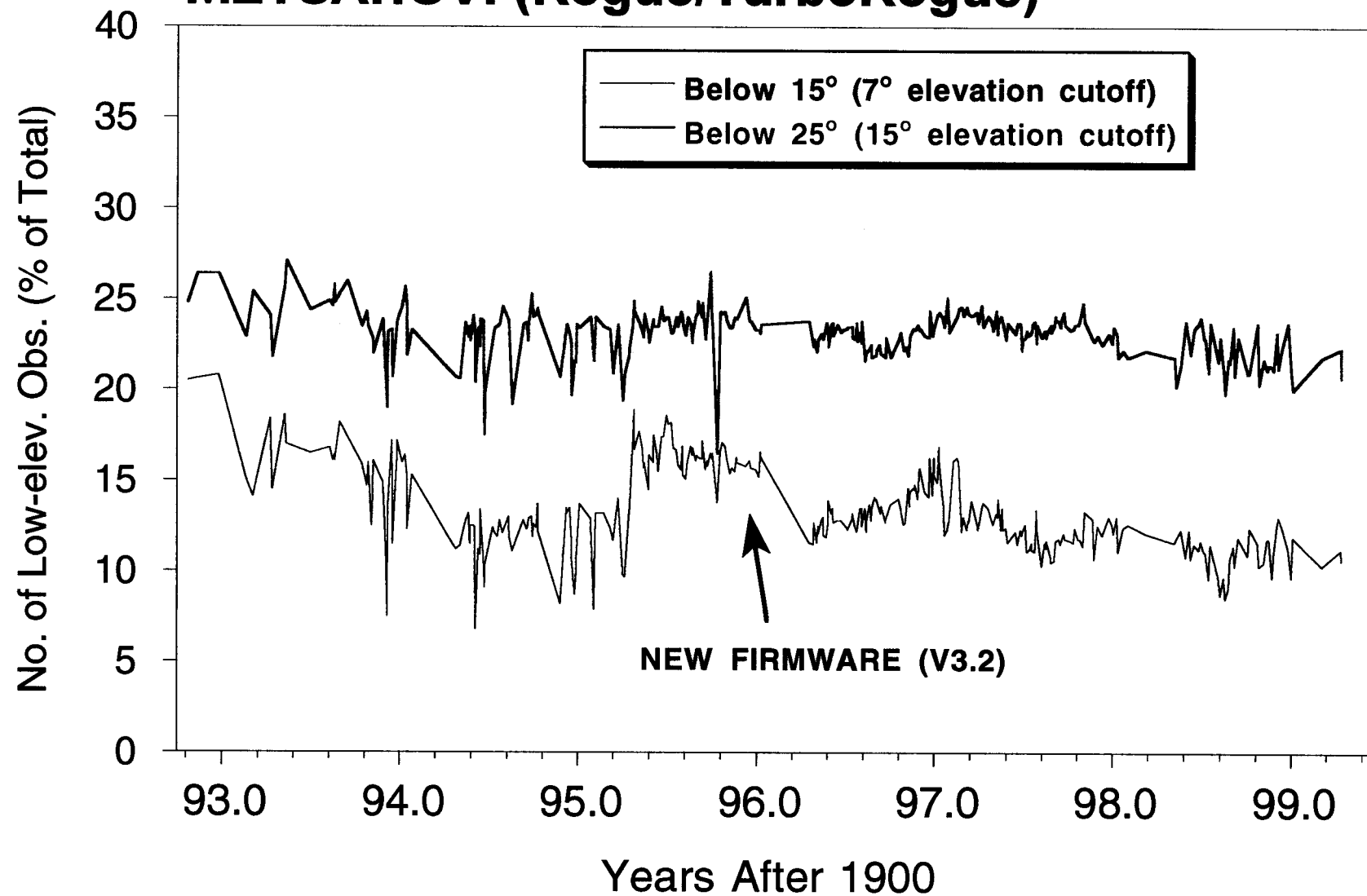
BERMUDA (TurboRogue)



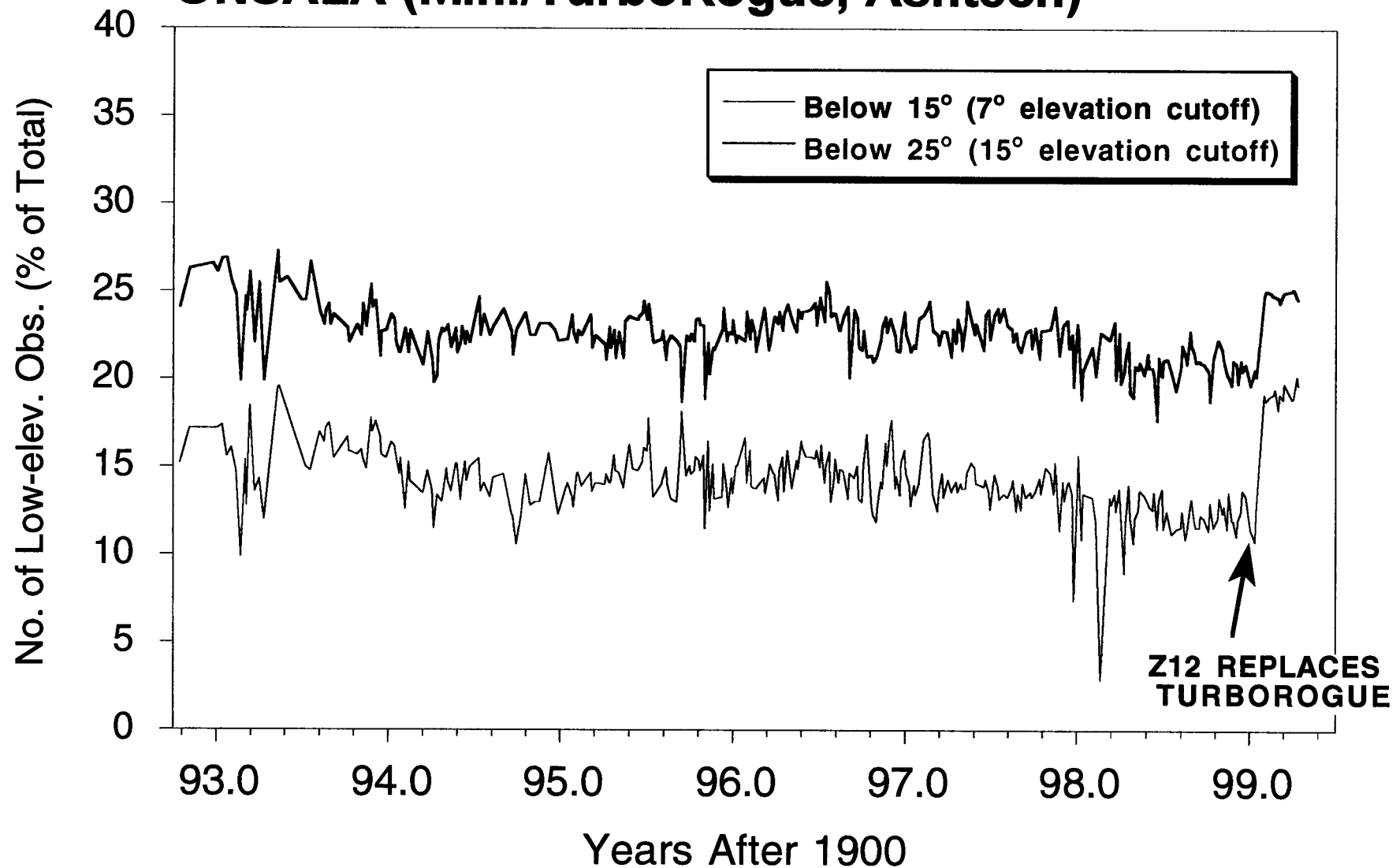
HARVEST (TurboRogue)



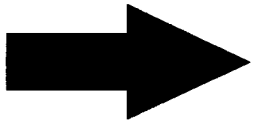
METSAHOVI (Rogue/TurboRogue)



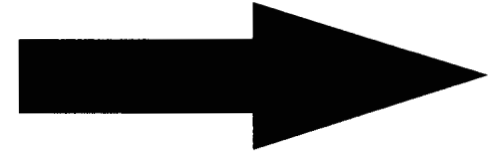
ONSALA (Mini/TurboRogue, Ashtech)



It is widely recognized that changes in GPS hardware (receivers and radomes) and site characteristics (obstructions) can significantly alter the recovery of vertical parameters. Receiving less attention are the potential impacts of receiver aging and changes in the firmware. The recent emergence of L2 tracking losses in early-generation TurboRogues has elevated the prominence of the firmware issue. The impact of the L2 problem has increased with the advance of the solar cycle since its low in late 1996. Low-elevation tracking at Bermuda and Harvest began to degrade at least two years before this. Note that the two high-latitude stations have stable low-elevation tracking histories. Conspicuously stable is Onsala, where the TurboRogue firmware was never changed.



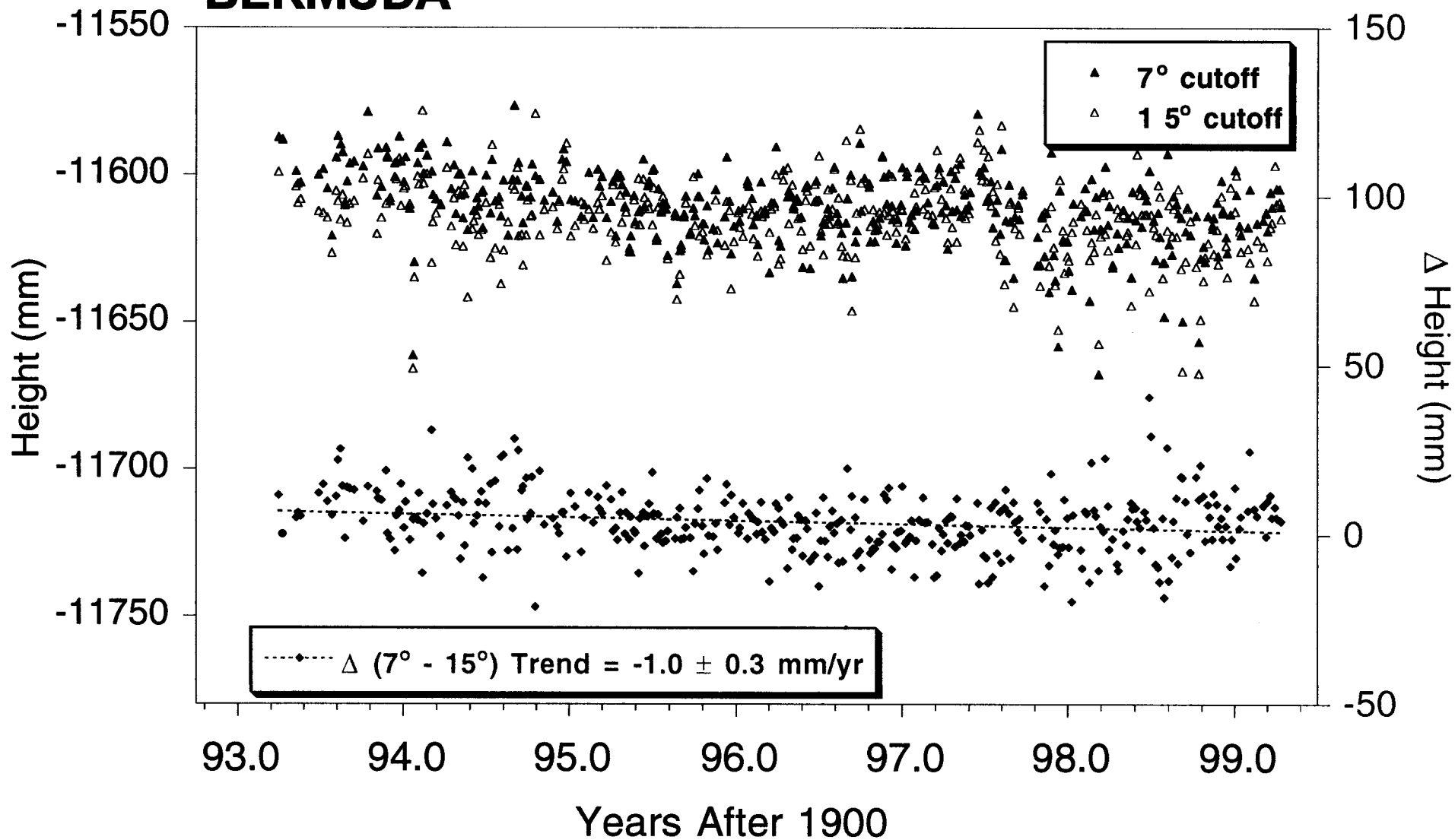
GEODETTIC HEIGHTS



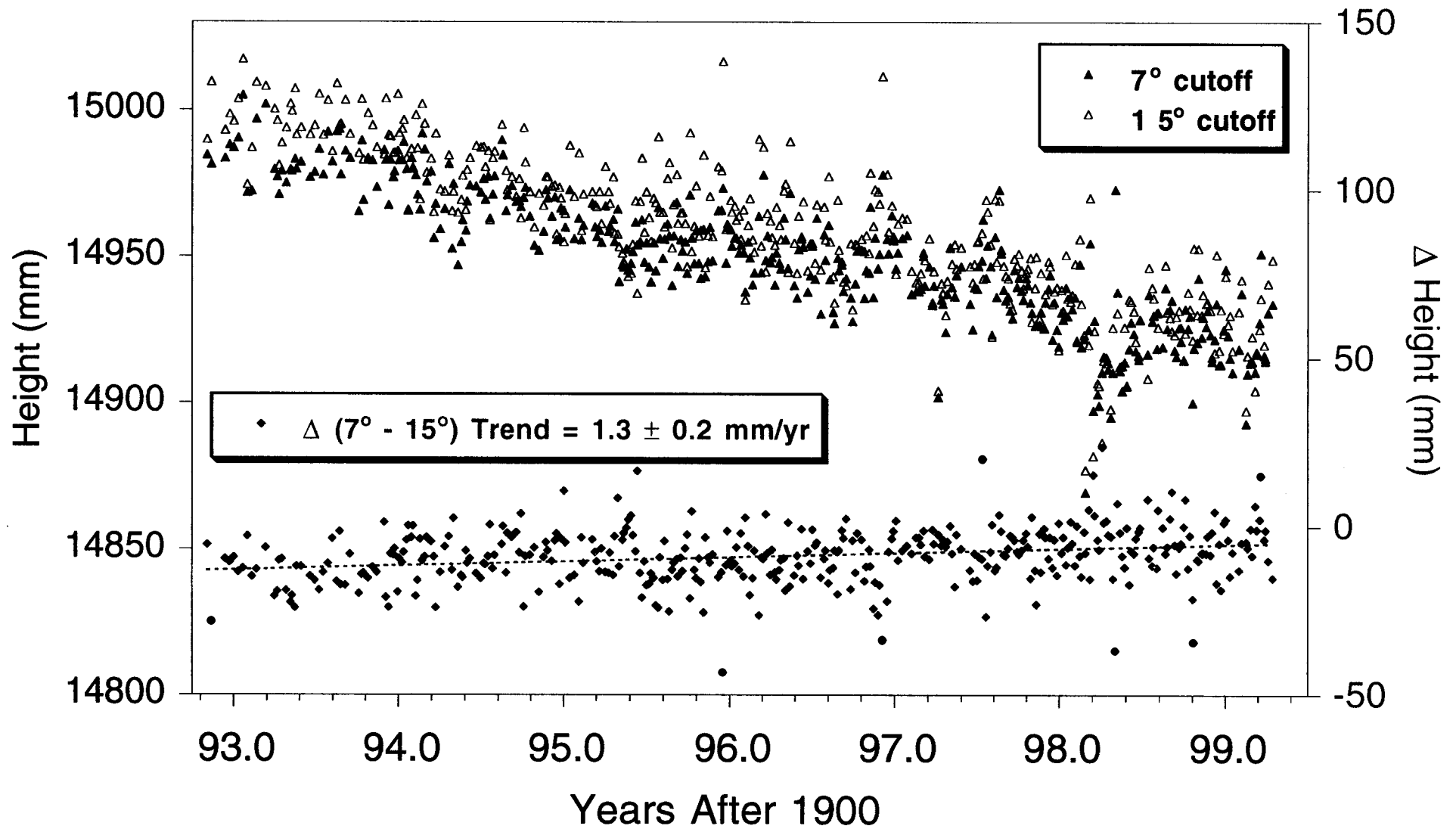
For the same four stations, we show time series (blue) of geodetic heights derived from solutions using two different elevation cutoffs (7° and 15°). Also given (in red) is the height difference between the 7° and 15° cases. To further stress the solution strategies, we estimated azimuthal troposphere gradients* in the in the 7° case, but not in the 15° case.

* Bar-Sever et al., *J. Geophys. Res.* 103(B3), 5019–5035, 1998.

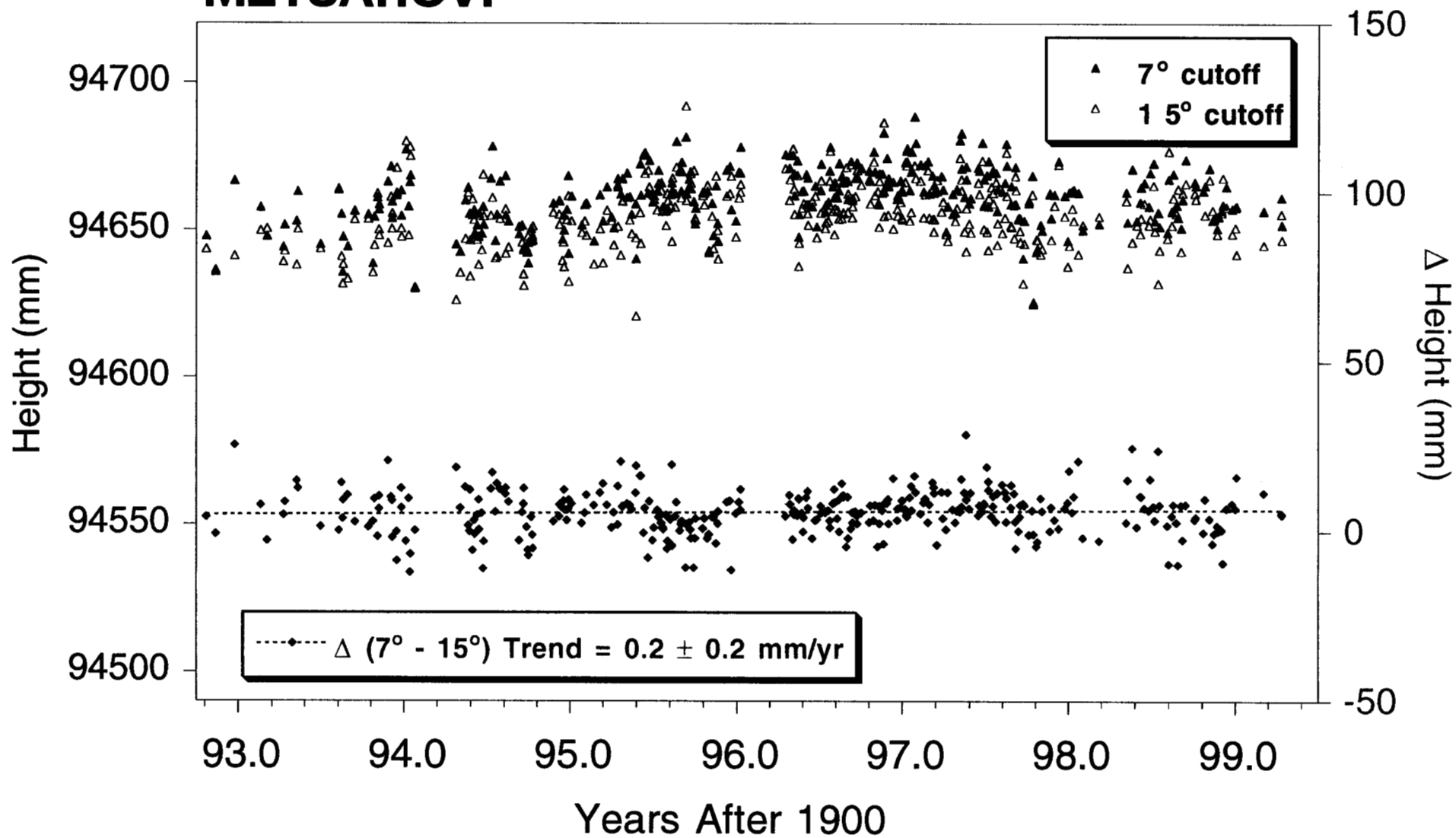
BERMUDA



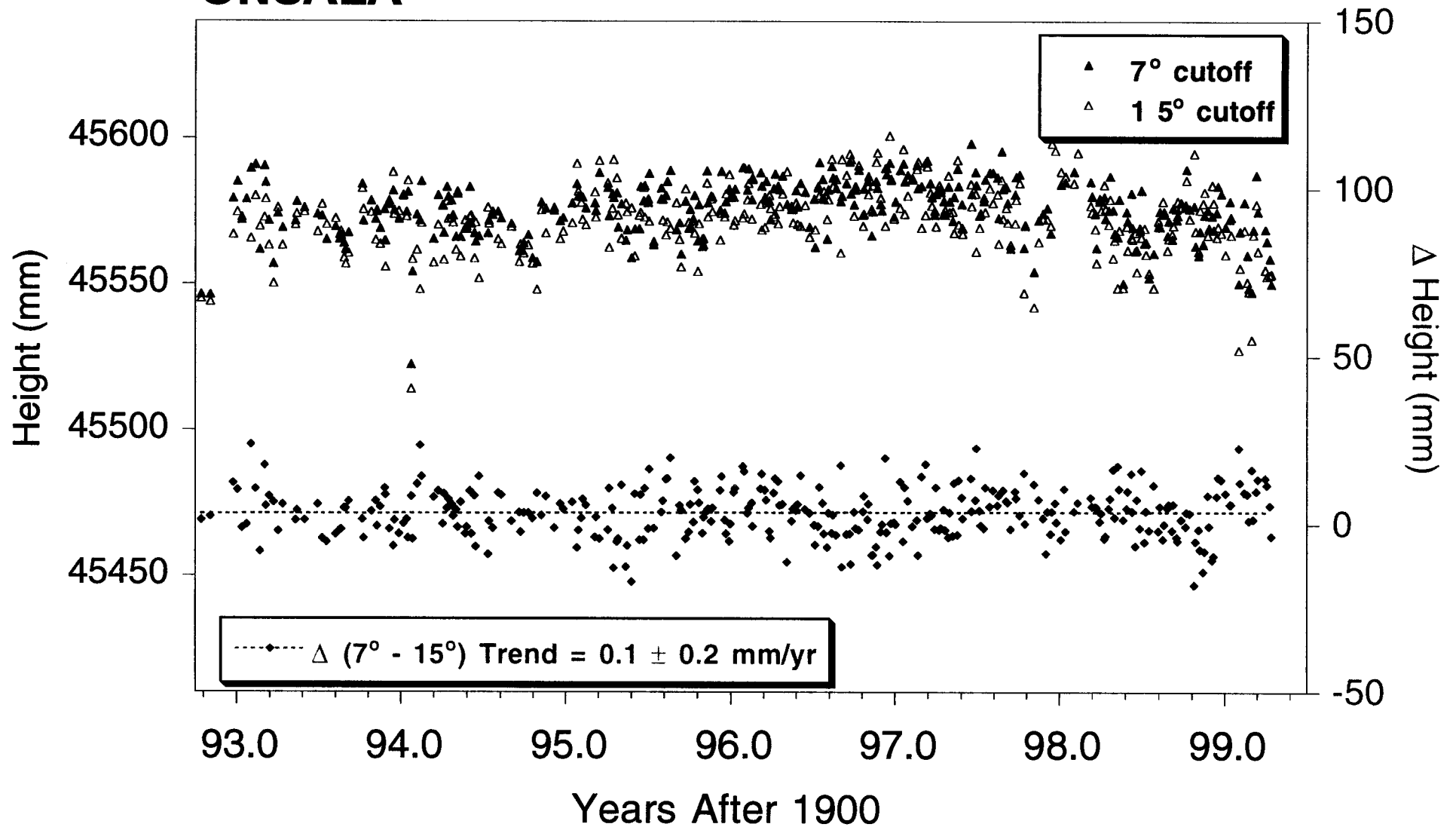
HARVEST



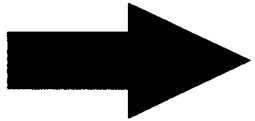
METSAHOVI



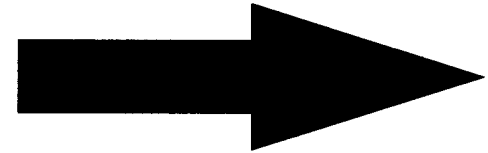
ONSALA



The vertical rates for the two stations with stable low-elevation tracking histories (Onsala, Metsahovi) have negligible sensitivity to elevation cutoff ($\ll 1$ mm/yr). In contrast, vertical rates from Bermuda and Harvest are sensitive to elev. cutoff at the 1 mm/yr level. While this level of error is not considered a detriment to many studies, it represents a potentially large contributor to the error budget for many specialized applications. As an example, Harvest serves as the prime NASA calibration site for the Topex/Poseidon (T/P) altimeter mission. Any error in the estimate of the large subsidence rate (~ 8 mm/yr) will map directly into estimates of the altimeter drift rate. Achieving an accuracy of 1 mm/yr for the vertical-rate estimates at Harvest is critical for corroborating the emerging record of global sea-level change from T/P.



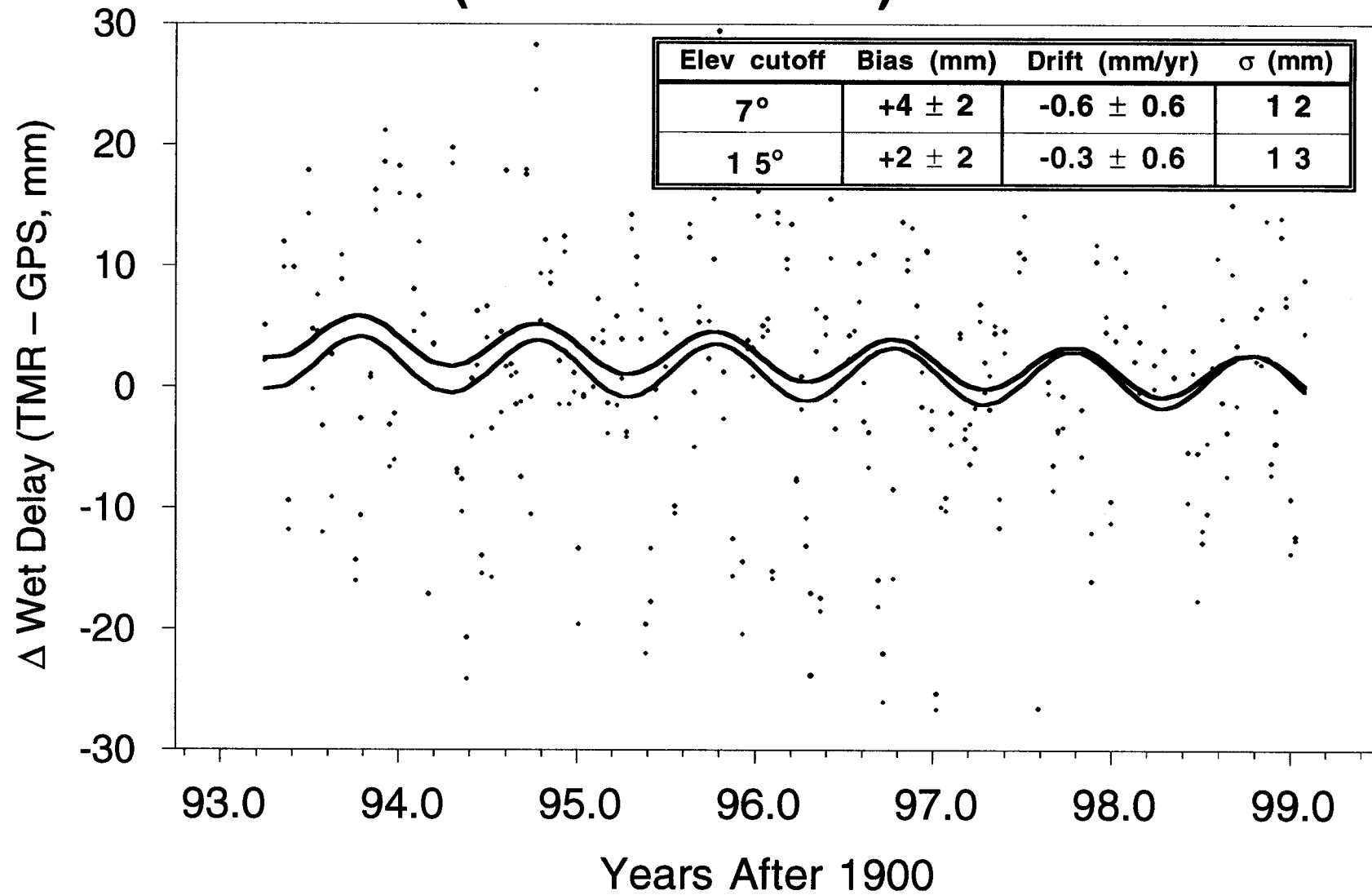
ZENITH WET DELAY



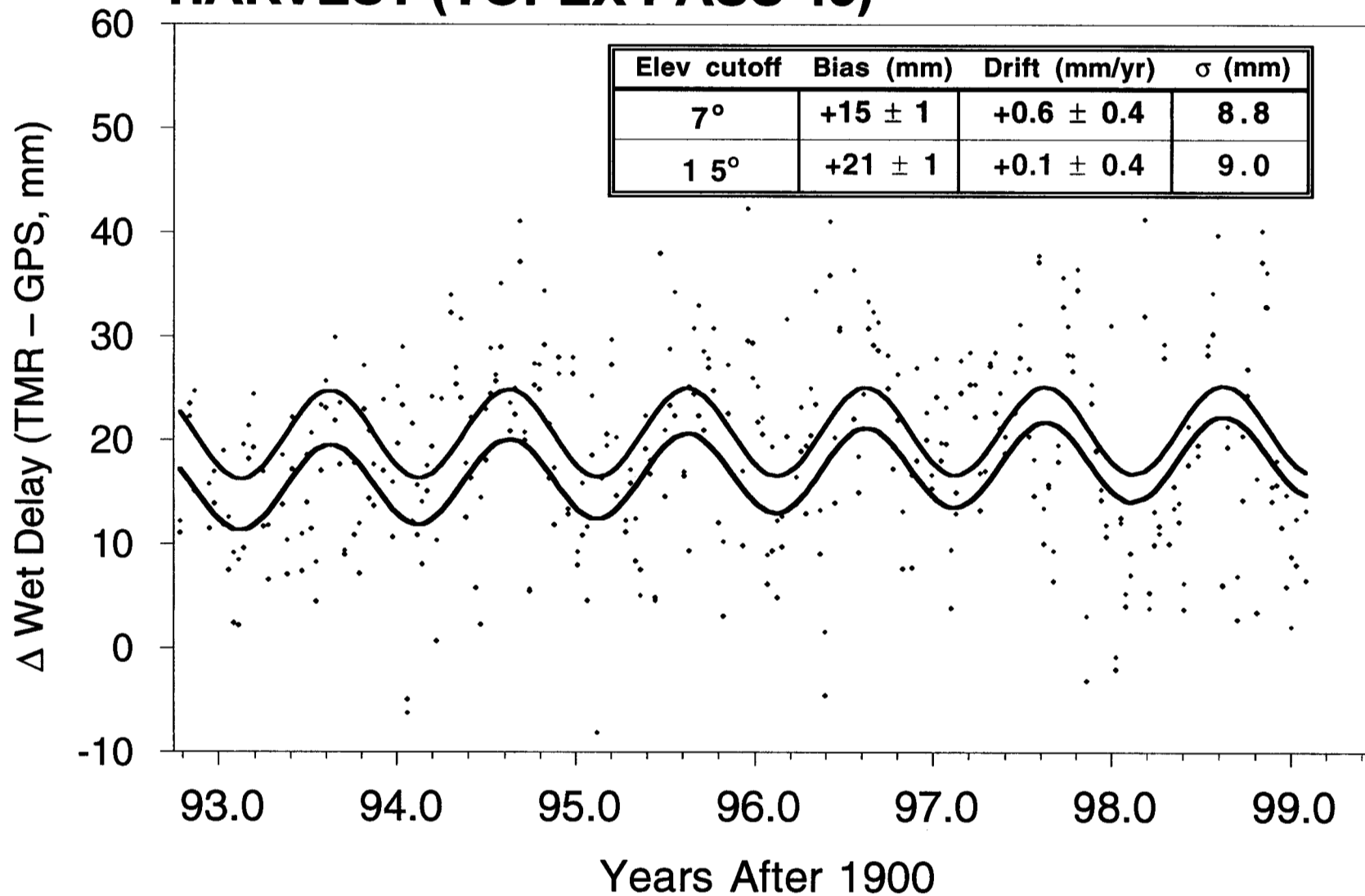
To quantify the influence of the low-elevation tracking trends on the zenith wet delay, we compared the GPS delays with those from the spaceborne Topex microwave radiometer (TMR). Shown here are time series of the instantaneous differences (TMR–GPS) for open-water Topex repeat passes in the vicinity of the four GPS stations. The TMR data have been corrected for a spurious drift of -1.2 mm/yr, the characterization of which was significantly influenced by the GPS comparisons.*

* Haines and Bar-Sever, *Geophys. Res. Lett.*, 25(19), 3563–3566, 1998.

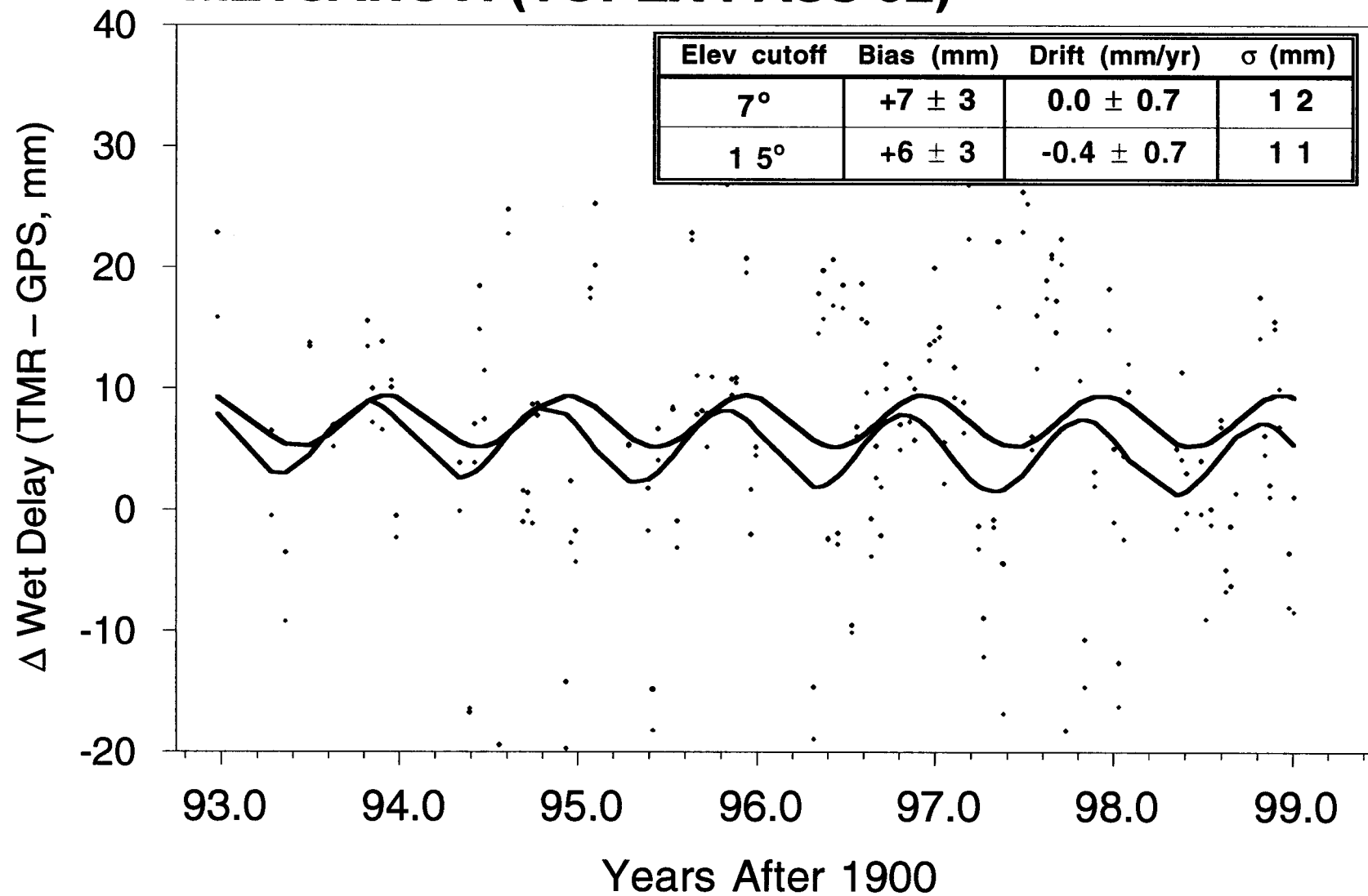
BERMUDA (TOPEX PASS 39)



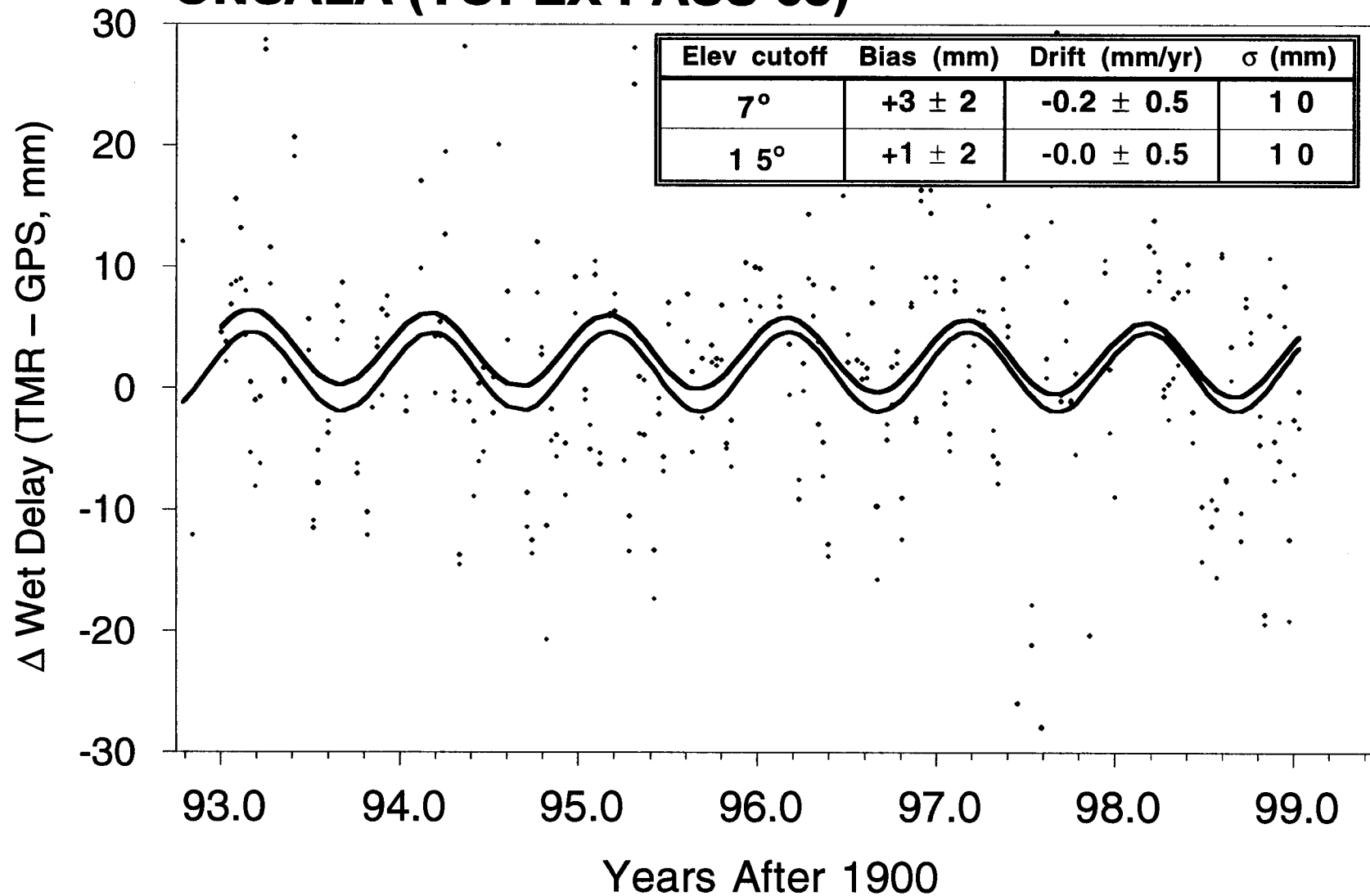
HARVEST (TOPEX PASS 43)



METSAHOVI (TOPEX PASS 92)



ONSALA (TOPEX PASS 68)

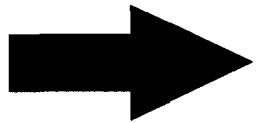


Synopsis: Latest results of the TMR/GPS comparisons of columnar water vapor

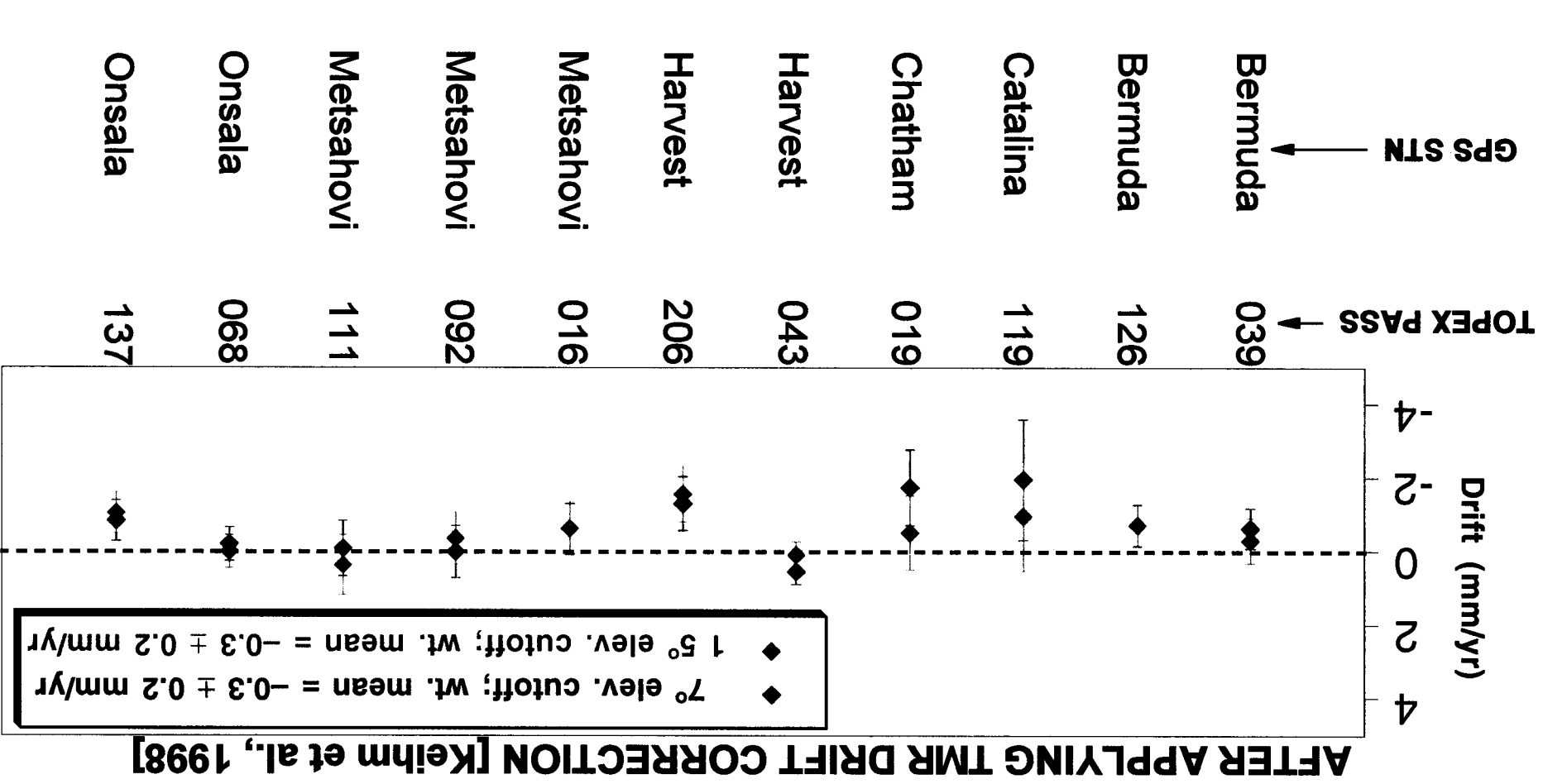
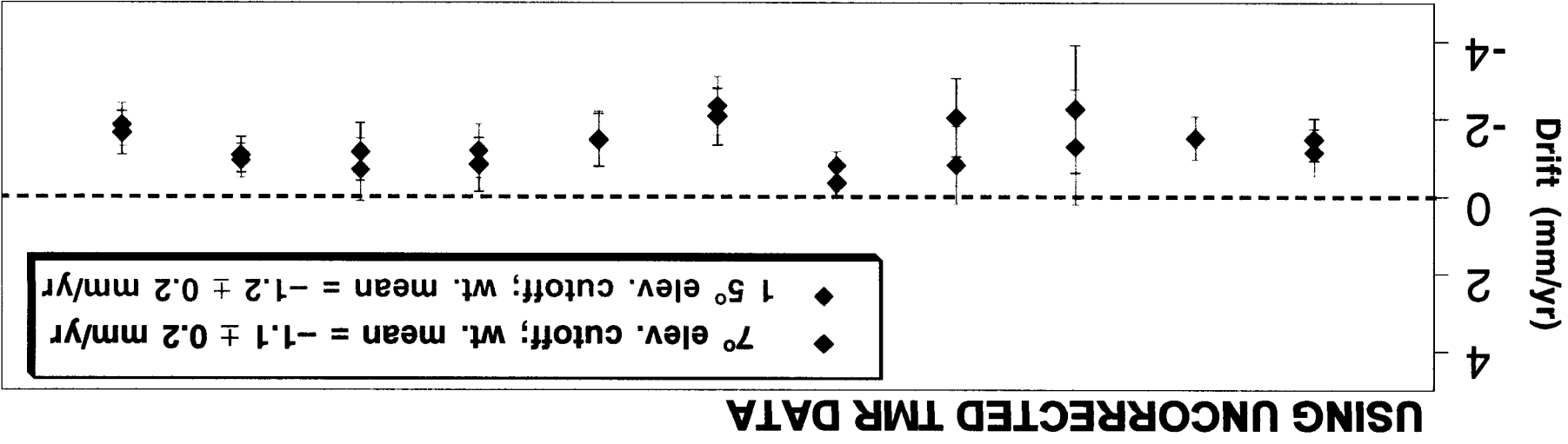


GPS-inferred water vapor measurements from the sites discussed in the poster played an important role in identifying a drift in the measurements from the Topex microwave radiometer. Shown here are updated TMR–GPS water-vapor drift estimates for 11 different station/pass pairs. Two additional stations near open-water Topex repeat passes have been included in this analysis (Chatham Island and Santa Catalina Island.)

The results suggest that the sensitivity of the trends in the TMR–GPS time series to changes in the abundance of low-elevation data is at the level of 0.0–0.5 mm/yr. (Addl. station/pass pairs were examined and show similar behavior).



In the TMR calibration exercise, the drift of the path delay measurements is sought with an accuracy of much better than 1 mm/yr. To overcome potential systematics introduced by low-elevation trends at any single GPS station, we use multiple station/pass pairs and ensure that the overall result is not significantly altered by changes in the elevation cutoff or by the introduction of an azimuthal gradient term in the troposphere estimation (see Appendix).



Acknowledgement

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